

**Bonneville Power Administration
Fish and Wildlife Program FY99 Proposal Form**

Section 1. General administrative information

**Gas bubble disease research and monitoring of
juvenile salmonids**

Bonneville project number, if an ongoing project 9602100

Business name of agency, institution or organization requesting funding

U.S. Geological Survey, Biological Resources Division

Business acronym (if appropriate) USGS-BRD

Proposal contact person or principal investigator:

| | |
|-----------------|---|
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Subcontractors. List one subcontractor per row; to add more rows, press Alt-Insert from within this table

| Organization | Mailing Address | City, ST Zip | Contact Name |
|--------------|-----------------|--------------|--------------|
| none | | | |
| | | | |
| | | | |

NPPC Program Measure Number(s) which this project addresses.

5.6.E.1

NMFS Biological Opinion Number(s) which this project addresses.

RPA 16: "The BPA, COE, and BOR shall participate in the development and implementation of a monitoring and evaluation program to investigate the effects of dissolved gas supersaturation. This program will include the physical and biological

monitoring components of a dissolved gas monitoring plan developed by the NMFS in consultation with the COE, BPA, BOR, FWS, and NBS prior to March 10, 1995".

RPA 17: "The BPA shall participate with the NMFS in activities to coordinate the regional passage and life cycle models and to test the hypotheses underlying those models".

Other planning document references.

If the project type is "Watershed" (see Section 2), reference any demonstrable support from affected agencies, tribes, local watershed groups, and public and/or private landowners, and cite available documentation.

Proposed Recovery Plan for Snake River Salmon (March, 1995): Task 2.2b, "Establish upper limits of allowable gas supersaturation levels to reduce the risk of gas bubble disease in fish"; Task 2.2d, "Conduct monitoring, evaluation, and research of the effects of spill on salmon migrants".

Subbasin.

Snake, Mainstem

Short description.

Conduct work on juvenile salmonids, including: 1) laboratory studies of gas bubble disease (GBD) to determine signs appropriate for monitoring, 2) field studies of vertical and horizontal distribution of individuals to determine behavior and risk of GBD; 3) training and QA/QC for monitoring.

Section 2. Key words

| Mark | Programmatic Categories | Mark | Activities | Mark | Project Types |
|------|-------------------------|------|------------------|------|-----------------------|
| X | Anadromous fish | | Construction | | Watershed |
| | Resident fish | | O & M | | Biodiversity/genetics |
| | Wildlife | | Production | | Population dynamics |
| | Oceans/estuaries | X | Research | + | Ecosystems |
| | Climate | + | Monitoring/eval. | | Flow/survival |
| | Other | | Resource mgmt | X | Fish disease |
| | | | Planning/admin. | | Supplementation |
| | | | Enforcement | | Wildlife habitat en- |
| | | | Acquisitions | | hancement/restoration |

Other keywords.

Gas Bubble Disease, Vertical Distribution

Section 3. Relationships to other Bonneville projects

| Project # | Project title/description | Nature of relationship |
|-----------|---------------------------|------------------------|
| none | | |
| | | |
| | | |

Section 4. Objectives, tasks and schedules

Objectives and tasks

| Obj 1,2,3 | Objective | Task a,b,c | Task |
|--------------|--|---------------|--|
| 1 | Determine significance of GBD in juvenile salmonids migrating in the Snake and Columbia rivers | a | Monitor the incidence and severity of GBD in juvenile salmon and/or steelhead collected at Lower Granite, Little Goose, Lower Monumental, Rock Island, McNary, John Day, and Bonneville dams during the smolt migration. |
| | | b | Participate in analysis of GBD signs in juvenile salmonids collected from in-river sampling to determine if fish sampled at dams have GBD signs equal to those in fish in the river. |
| 2 | Determine optimal method for detecting and assessing GBD in juvenile salmonids. | a | Construct a gas supersaturation system which will be expanded before the 1997 season to optimize research productivity. |
| | | b | Assess the progression and quantify the severity of signs of GBD in juvenile salmonids exposed to different levels of total dissolved gas and temperatures. |
| | | c | Relate signs of GBD to the likelihood of mortality, based on prevalence, severity and individual variation. |
| | | d | Mimic <i>in-situ</i> exposures (Objective 3) of juvenile chinook salmon and steelhead under controlled conditions and determine their GBD signs and mortality. |
| 3 | Determine <i>in-situ</i> vertical distribution of individual | a | Investigate technologies for reducing the size of the current |

| | | | |
|---|--|---|---|
| | juvenile salmonids migrating in water with high total dissolved gas. | | pressure-sensitive radio transmitter for use in juvenile spring chinook salmon. |
| | | b | Determine depth histories of individual juvenile salmonids in a Columbia or Snake river reservoir. |
| | | c | Determine depth histories of individual juvenile salmonids in the near-dam forebay of a Columbia or Snake river dam. |
| 4 | Determine sublethal effects of exposure to gas supersaturated water on juvenile salmonids. | a | Determine if juvenile salmonids with bacterial kidney disease (BKD) experience increased mortality or severity of <i>Renibacterium salmoninarum</i> (RS) infection as the result of exposure to water with dissolved gas supersaturation (DGS). |
| | | b | Determine if exposure to water with DGS increases the mortality of juvenile chinook salmon when they encounter <i>Vibrio anguillarum</i> , a marine fish pathogen. |
| | | c | Determine if the availability of compensation depth mitigates for the effects of water with DGS on disease resistance of juvenile chinook salmon. |
| | | d | Determine if exposure to water with DGS increases the likelihood of horizontal transmission of BKD. |

Objective schedules and costs

| Objective # | Start Date mm/yyyy | End Date mm/yyyy | Cost % |
|--------------------|-------------------------------|-----------------------------|---------------|
| 1 | 04/1999 | 04/2001 | 5 |
| 2 | 04/1999 | 04/2001 | 10 |
| 3 | 04/1999 | 04/2001 | 75 |
| 4 | 04/1999 | 04/2001 | 10 |
| | | | |

Schedule constraints.

This project requires funding approval prior to 01 March each year to enable purchase and setup of field equipment to allow proper data collection.

Completion date.

FY 2000

Section 5. Budget***FY99 budget by line item***

| Item | Note | FY99 |
|---|--|----------------|
| Personnel | | 416,751 |
| Fringe benefits | | 96,901 |
| Supplies, materials, non-expendable property | | 22,500 |
| Operations & maintenance | | 46,923 |
| Capital acquisitions or improvements (e.g. land, buildings, major equip.) | | 0 |
| PIT tags | # of tags: 120 RADIO TRANSMITTERS | 60,000 |
| Travel | | 30,400 |
| Indirect costs | Overhead | 241,070 |
| Subcontracts | | 0 |
| Other | | 0 |
| TOTAL | | 914,545 |

Outyear costs

| Outyear costs | FY2000 | FY01 | FY02 | FY03 |
|-------------------|---------|------|------|------|
| Total budget | 918,019 | | | |
| O&M as % of total | 5.1 | | | |

Section 6. Abstract

This project has three main goals. They are to determine the risk of GBD of juvenile salmonids by determining *in-situ* exposures to total dissolved gas (TDG) and mimicking them in the laboratory, to determine the sub-lethal effects of TDG, and to provide training and QA/QC for the biological monitoring program.

The first goal benefits fish through analysis of GBD risk based on actual exposure of individual migrants. This approach is the most appropriate manner to determine signs and mortality. Current methods, based on fish collected via dam bypass systems and

purse seines, are limited to a “snapshot” of the overall picture. Our method results in a more complete picture based on actual exposure histories (e.g., in 1997 results indicated exposure varied with reservoir area and time of year, and that vertical movement of individuals was common; this information was previously undocumented). The second goal will increase understanding of the effects high TDG have on mortality from altered disease resistance.

Current decisions and models about the exposures to GBD are based on an untested theory of a static vertical distribution of fish. Research in 1997 indicated this view was incorrect, which could result in overestimates of GBD incidence and fish mortality. We propose to determine signs and mortality resulting from exposures of individuals by mimicking them under controlled conditions. Results will indicate if prevalence and severity of GBD signs detected through the monitoring program are reasonable given actual exposures of fish. This research requires exposure histories from 1-2 additional years.

Section 7. Project description

a. Technical and/or scientific background.

Knowledge of the distribution of fishes in the Columbia and Snake rivers is needed to evaluate risks of gas supersaturation to these animals. Gas supersaturation in these rivers results chiefly from spill at dams. Exposure of fish to gas supersaturated water can result in Gas Bubble Disease (GBD), which can result in direct impairment or death due to gas emboli in the gills and tissues. Indirect mortality also occurs through increased susceptibility to predators (Mesa and Warren 1997), but little is known about other sub-lethal factors. Concerns about the risk of GBD in fishes in the Columbia Basin have heightened with the recent increased use of spill as a fish passage method (NMFS Biological Opinion RPA #2) and the high flows during 1995-97.

The vertical distribution of fish may be the most important factor determining the severity of GBD. Fish in water with high total dissolved gas (TDG) may not experience GBD if they are at sufficient depth. Each meter of depth affords compensation of approximately 10% of supersaturation (Weitkamp and Katz 1980). For example, a fish maintaining a depth of at least two meters will not be affected by a TDG of 120% at sea level, whereas most fish at shallow depths begin to exhibit signs of GBD in about 10 h. This compensation is a result of hydrostatic pressure increasing the solubility of dissolved atmospheric gasses in water and in the blood and tissues of aquatic animals.

The importance of the vertical movements of individuals is apparent from studies of fish recovery from GBD documented since the early 1900's (Gorham 1901; Dawley and Ebel 1975; Weitkamp 1976). Studies have shown that recovery can be accomplished with time in equilibrated water or by increasing fish depth in supersaturated water. Knittle et al. (1980) found that 3 hours at a depth of three meters was sufficient for

juvenile steelhead to fully compensate from near-lethal surface exposures to 130% TDG, and resulted in additional protection from GBD when fish were returned to the surface. Thus, the effects of high TDG cannot be understood or predicted without information about the vertical histories of individuals due to the recovery and protection from GBD afforded by depth.

Few studies have examined the *in-situ* vertical distribution of individual salmonids in the Columbia River basin. Past studies were based on hydroacoustic and gill net methods which work at the population level and cannot discern the movements of individuals (Monan et al. 1969; Smith 1974; Thorne et al. 1992). The only study of the vertical distribution of individual salmon conducted in the Columbia or Snake Rivers was an investigation of adult chinook salmon using pressure-sensitive radio transmitters (Gray and Haynes 1977). No work on individual juvenile salmonids has been conducted prior to this project, though the need for such research was recognized as early as 1980 (Weitkamp and Katz 1980).

The main reason there has been no work on juvenile individuals is the lack of tools of a suitable size. This project pressed manufacturers to miniaturize a pressure-sensitive radio transmitter for use in juvenile salmonids. The result was a new tool for the research community and the ability to remotely-monitor vertical movements of individual juvenile salmonids for the first time (Beeman et al., in press).

Knowledge of direct and indirect factors affecting fish survival relative to GBD is needed to evaluate the benefit of increased spill as a fish passage method. Indirect mortality due to GBD is known to occur via increases in predation (Mesa and Warren 1997), but little is known about other factors. Research under Objective 4 of this proposal will determine if exposure to water with high TDG affects resistance to bacterial kidney disease (BKD) and vibriosis - two common pathogens of juvenile salmonids.

The results of this study will help us understand the effects of dissolved gas supersaturation on juvenile salmonids. This research is required under the NPPC Fish and Wildlife Program measure 5.6E.1. Further research is needed because there is a clear disparity between effects based on laboratory studies and results from migrating fish obtained through the Biological Monitoring Program. The NMFS Biological Opinion RPA #2 called for the use of spill as a fish passage method. The RPA #16 specified that a biological monitoring and evaluation program be instituted to monitor GBD in salmonid fishes due to the GBD risks associated with spill. Few signs of GBD have been found by the program, despite the prevalence of ambient in-river gas levels known to cause mortality in shallow-tank laboratory experiments. One approach of this proposal is to determine the *in-situ* vertical and horizontal histories of individual juvenile salmonids in relation to ambient gas levels. These results can then be mimicked in a controlled setting to determine the incidence and severity of GBD and any mortality that may occur. These data will then be compared to results of the biological monitoring program. A second approach of this proposal is to examine indirect mortality from reduced disease resistance due to high TDG.

Results of this study will aid regional passage and life cycle models. The NMFS Biological Opinion RPA #17 identifies the need for such research. Current models, such as the CRiSP model of salmon passage, are based on a simplistic fish distribution model in which individuals do not change their depths during migration. Results of our study in 1997 indicate this is not the true state of nature, and that vertical movements of individuals occur often. Results in 1997 indicate the CRiSP model may overestimate mortality from GBD due to its assumption of a static fish distribution. The US Army Corps of Engineers is working on a model to predict mortality due to GBD. This model has gas distribution and fish distribution components. The fish distribution component is to be based on data from this project.

Project personnel are experienced researchers in the field of fish physiology and GBD. Their most recent work includes field studies of vertical and horizontal distribution of juvenile salmonids (1996-present) and laboratory studies of the progression of GBD signs and susceptibility to predation (1994-present). They were also involved in research leading to the selection of methods for biological monitoring of GBD and conducted the first year of biological monitoring in 1995. They currently oversee QA/QC and training for the monitoring program. They have published two recent manuscripts related to GBD (Mesa and Warren 1997; Beeman et al., in press).

b. Proposal objectives.

1. Determine significance of GBD in juvenile salmonids migrating in the Snake and Columbia rivers.

Our role under this objective has been reduced. We originally developed the methods and protocols of the Biological Monitoring Program, including training, QA/QC, and examinations of fish at monitoring sites. Our new role has been reduced to training and QA/QC. Members of the Smolt Monitoring Program are now examining fish for GBD along with their other duties at the monitoring sites.

2. Determine optimal method for detecting and assessing GBD in juvenile salmonids.

Identify progression of external signs of GBD in juvenile salmonids and identify those appropriate for a system-wide monitoring effort. This research assumes there are external signs indicative of GBD and that at least one sign is related to time and/or severity of exposure. Laboratory experiments are conducted on juvenile chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) at several temperatures and gas levels. The prevalence and severity of signs and mortality are examined during each trial. Signs showing progressive changes in severity and incidence are identified as having potential for use in the system-wide biological monitoring. Correlation and regression techniques are used to identify signs useful in the prediction of mortality based on exposure. Results will be submitted to BPA through quarterly and annual reports and to the scientific community through the peer-reviewed literature.

This objective will also determine the mortality and signs of GBD in fish receiving exposure to water with high TDG based on *in-situ* exposures determined in Objective 3. These trials could be taken to a specific end point (e.g., LT 10 or LT 50), or they could be run for a specific time of exposure (e.g., typical time to migrate through a reach of river).

3. Determine *in-situ* vertical and horizontal distribution of individual juvenile salmonids migrating in water with high total dissolved gas.

This objective is a field study of fish distribution based on radio telemetry. Critical assumptions include: 1) tagged fish behave as untagged fish, 2) the radio signal can be detected at depths fish occupy, 3) fish will encounter supersaturated water during at least one year of study, and 4) repeated measures can be collected from individuals. The outcome of this objective will be a database of repeated measures from individuals including date, time, fish depth, TDG, water temperature, water depth, and spatial location. This data will be available for use in regional models dependent on fine-scale fish distribution information. Results will be submitted to BPA through quarterly and annual reports and to the scientific community through the peer-reviewed literature.

4. Determine sub-lethal effects of exposure to gas supersaturated water on juvenile salmonids.

This objective examines the effects of GBD on the ability of juvenile salmonids to resist disease. The effects of GBD on fish infected with bacterial kidney disease (BKD; *Renibacterium salmoninarum*), a highly prevalent disease of salmon, will be tested. The ability of fish with GBD to resist the marine pathogen *Vibrio anguillarum*, the causative agent of vibriosis, will also be tested. Chronic and acute exposures will be used. The basic hypotheses are: 1) The mortality (or signs of GBD) of fish infected with BKD is significantly greater than control fish, and 2) the mortality due to vibriosis of fish with signs of GBD is significantly greater than those of control fish. Each hypothesis assumes mortality is due to the test condition. Results will be submitted to BPA through quarterly and annual reports and to the scientific community through the peer-reviewed literature.

c. Rationale and significance to Regional Programs.

The Fish and Wildlife Program (FWP) calls for research of dissolved gas supersaturation and its effects on juvenile salmonids (measure 5.6E.1). Our objectives address this measure directly. However, our approaches (i.e., individual-based distribution and sub-lethal effects of TDG) are somewhat different than others.

Our fish distribution work is based on individuals rather than on populations. All other work has been population based. These include BPA # 9300802 “Symptoms of Gas Bubble Trauma due to gas supersaturation”, a study examining fish captured with a purse seine, and US Army Corps of Engineers (COE) DGAS #97-(2)-1 “Evaluation of horizontal and vertical distribution of juvenile salmonids in the Lower Snake and

Columbia rivers in relation to total dissolved gas”, a study using mobile hydroacoustic methods to describe distributions. The former study is conducted to validate results of the biological monitoring program. The latter is to collect data for validation of a COE model to predict fish mortality based on gas and fish distribution; the fish distribution aspect of this model is to come from data produced by the study described in this proposal.

The main difference between these studies and ours is the individual-based method of our study can describe vertical movements of individuals whereas the population-based methods cannot. The advantage of this is that the true exposure of the fish can be described accounting for changes in exposure due to varying hydrostatic compensation and spatial location. The disadvantage of individual-based methods is they are extremely labor-intensive and result in small sample sizes.

The only individual-based method appropriate for small fishes at this time is radio telemetry. This method is constrained by poor radio signal transmission through water, limiting the research to fish at depths of approximately 10 m or less. Hydroacoustic methods are not bound by this constraint, but they cannot discern the species of their targets. Purse seines do have depth limitations. The radio telemetry method is available as a direct result of work this project completed in 1996.

There is currently no other research to address sub-lethal effects of TDG in the region. However, previous research has been conducted at our laboratory (Mesa and Warren 1997). This research indicated significant indirect mortality due to predation. It is reasonable to assume there are other indirect factors of mortality as well.

The results of this research are needed to 1) evaluate the existing Biological Monitoring Program, 2) update the distribution subroutine in a regional passage model (CRiSP), 3) serve as a database of fish distribution in a new model of dissolved gas supersaturation and mortality (COE DGAS program), 4) determine true exposure histories of individuals, 5) mimic those exposures in controlled experiments to determine the GBD signs and mortality they may cause, and 6) determine sublethal effects of TDG. This study also performs training and QA/QC for the Biological Monitoring Program.

d. Project history

This project, BPA # 9602100, was initiated in 1996 and continued in 1997. Previous work, consisting of the hands-on monitoring in the regional Biological Monitoring Program, was conducted under project BPA # 8740100 “Assessment of smolt condition for travel time analysis”. Additional work was also conducted under BPA # 8200300, “Significance of predation and development of prey protection measures for juvenile salmonids in the Columbia and Snake river reservoirs”. Previous costs were 1,401,615. Annual reports to BPA have been submitted, but have not been distributed by BPA as of January, 1998. Two publications in peer-reviewed journals have been produced: one under #9602100 (Beeman et al., in press) and one under #8200300 (Mesa

and Warren 1997).

Research to date has had several management implications. Results of laboratory studies have indicated bubbles in the fins and lateral line are the most appropriate for monitoring purposes. Bubbles in the gills, the proximate cause of death due to GBD, exhibit a threshold response and are not a useful sign to monitor in live fish as they predominantly occur in moribund ones. Further research indicates the use of external signs to predict mortality is limited without knowledge of previous exposure due to high individual variation, differences in rates of incidence, and similarities in signs at different gas levels. These results have been used to determine the signs to use in the Biological Monitoring Program.

Data on vertical and horizontal distribution of individuals collected in 1997 indicated risk of GBD varied with reservoir area, species, and time of year. The management implications of these results are that current biological monitoring, which is based on collection systems in dam forbays, obtains fish from the area of the reservoir where they are least likely to bear signs of GBD. The greatest risk of GBD was found in the tailrace area, with risk decreasing from the tailrace to the forbay. Other validation methods, chiefly purse seining (BPA # 9300802), also do not examine fish in the tailrace areas because they cannot be used safely in the high water velocities present there. However, our research also indicated the overall exposure of juvenile salmonids was such that few signs should be present in the forebay, which agreed with observed data from the Biological Monitoring Program and purse seine study.

e. Methods. Objective and tasks refer to Section 4: Objectives, tasks and schedules.

Objective 1. Significance of GBD in migrants.

Task A will entail training investigators for the Biological Monitoring Program and checking their work during the migration season. At least one training session will be conducted at the Columbia River Research Laboratory. Training includes classroom instruction about the basic causes and physiological effects of gas bubble disease, how to evaluate the severity of GBD signs, and recording data. The training includes laboratory work examining fish with GBD. The biologists are taught standardized methods to count bubbles in the lateral line, to recognize fin bubbles, and to rank the severity of bubbles in the fins. A standardized system of non-lethal fish anesthesia and sampling is also demonstrated.

The in-season QA/QC is performed by a trained examiner through visits to each monitoring site. The examiner observes the technique of the on-site biologist. They also examine fish after the on-site biologist and compare results. The examiner visits each monitoring site several times during the migration season.

Objective 2. Method to detect and assess GBD.

Previous work has completed Tasks A and B. Current research is aimed at completion of Task C and the initiation and completion of Task D. Task C will be completed through correlation and regression analyses of data collected during 1995-1997.

The goal of Task D is to determine the progression of signs and mortality resulting from the controlled application of *in-situ* exposures derived from Objective 3. These tests will be conducted in a pressurized swimming chamber, or perhaps a tank tall enough to provide hydrostatic pressure sufficient for this task. This objective is based partly on the availability of a pressurized system purchased by BPA for previous dissolved gas work. Another could be built if it is not available to us.

Fish will be subjected to variations in pressure that mimic the vertical movements and travel history of individual salmonids in the wild. Sample sizes in each trial will depend on tank size. The *in-situ* data from fish in the wild will be combined into several scenarios for testing in the laboratory. The field data will be pooled by species and year (depending on similarities in river conditions and fish depths each year) and the pressure in the laboratory system varied to equal the median, upper quartile and lower quartile *in-situ* pressures in separate trials. Total dissolved gas during each trial will be set to the median of the field data; it will not be varied during a trial. The experiments will be carried out to the median time of exposure based on field data. Mortalities will be recorded and fish will be examined for signs of GBD at the end of each trial. Each trial will be repeated several times.

Objective 3. *In-situ* distribution.

Task A was largely completed in 1997. However, field testing possible prototypes with greater signal output may be needed. These tests will be designed to evaluate detection distances at various tag depths. No significant reduction in tag size is expected. Most work will be under tasks B and C.

This objective will be based on juvenile chinook salmon and steelhead of hatchery origin. Study fish will be obtained from the collection facility at Lower Monumental Dam due to the small number of fish collected at Ice Harbor Dam. Fish will be anesthetized, briefly inspected for signs of GBD, tagged, and allowed to recover 24-h prior to release.

Task B will result in information on fish movements as they migrate through a reservoir. Telemetry equipment used from boats will consist of one receiver and 6-element antenna on each of two or three boats. Additional equipment used to collect data will include global positioning systems, depth finders, and total dissolved gas meters. We will track fish using boats operating 24-h per day from the time of release until the time the tagged fish have entered the forebay boat restricted zone at McNary Dam.

We will use a tracking protocol designed to maximize the number of repeated contacts of individuals, as this is the strength of this technology. Each boat will be

assigned a prioritized list of fish (i.e., radio frequencies) to search for. Each boat will be responsible for contacting as many fish as possible at one-hour intervals; each vessel should be able to track 1-3 fish per release in this manner. This procedure will result in a depth and TDG exposure history from each fish consisting of data once each hour from release to passage at McNary Dam, approximately 24-96 hours.

We will also record fish depths once per minute during several 15-minute time periods each day. This data will be collected from one fish located from each boat near the times of sunrise, sunset, noon, and midnight. The boats will remain about 50-200 m from the fish while collecting this data to avoid affecting fish behavior. Fish depths and water temperature will be the only data collected during these periods. This will provide fine-scale information about the variability in fish depths.

The probability of detecting each individual will be partially dependent on their depth due to the attenuation of radio signals in water. This limitation is due to the physical properties of radio signals and the low power of the transmitters due to their small size. Tracking protocols were designed in 1996 such that the distances between boat tracks while searching for tagged fish are near enough to permit detection of fish at depths near the lower limit of detection. All data will be added to a geographical information system (GIS) database.

Task C will serve to collect detailed information about the vertical and horizontal distribution of tagged fish as they approach the dam (within about 100 m from the dam face) and pass via spill or the powerhouse, as well as an exit station to indicate when the fish have left the study area. This automated system is operated 24h per day and is a safe method to gather data from the boat restricted zone during periods of spill.

The aerial equipment mounted at the dam will consist of data-logging telemetry receivers collecting data from up to eight 4-element yagi antennas each. The antennas will be placed approximately 70 m apart across the powerhouse and spillway. This configuration will enable us to receive data from fish located up to 100 to 200 m upstream from the dam.

Data collected will be tested for normality prior to statistical analysis to determine whether parametric or non-parametric analyses are appropriate. The depths of individuals will be used to determine the percent of time each individual and all fish combined spent above and below the compensation depth in the reservoir and in the near-dam forebay of McNary Dam. The compensation depth will be determined from TDG data collected at each fish contact. Measures of central tendency and associated confidence limits will be calculated from the depths of each fish. Correlations between fish depth, TDG, and other factors will be examined for statistical significance.

Depth histories and TDG exposures will be compiled for each individual and for all individuals combined by species with reference to the time from their release. The uncompensated TDG, which is the effective TDG exposure after consideration of depth, will be compiled. This will enable researchers to reproduce this fish behavior in the

laboratory to determine if the TDG exposures result in GBD signs or mortality.

Objective 4. Sub-lethal effects of exposure to gas supersaturated water

For these experiments, we will distinguish between exposure to dissolved gas supersaturation (DGS) and the potential direct effects of that exposure, i.e., GBD. Because there is often wide variation in GBD signs of individuals and some of our experiments will test effects on fish that have survived an acute exposure to water with DGS, our experimental designs are based on exposure history as opposed to the presence of GBD signs.

Two different DGS-exposure histories will be examined: chronic exposure to low level of DGS (110% supersaturation at 12°C) for several weeks and acute exposure to 120% DGS for a few hours or days. In these experiments, we will monitor cumulative mortality, time-to-death of those that die, and progression and severity of infection (BKD only). All mortalities will be assessed for level of RS infection, or the systemic presence of *V. anguillarum*, and their gills will be examined for bubbles indicating mortality from GBD.

Task A. Bacterial kidney disease

Chronic DGS. -- We have used the waterborne method to successfully create populations of fish with varying severities of BKD infection (Mesa 1993). We will sample fish every five days for 30 days and assess severity of BKD and signs of GBD. Any mortalities will be examined for signs of GBD and sampled to determine severity of BKD infection.

Acute DGS. -- In earlier studies we found that chinook salmon exposed to water with 120% gas supersaturation experienced 50% mortality in about 60 h. Severity of BKD infection would not change significantly in 60 h, but the presence of the disease might alter the progression of GBD signs or the dynamics of GBD mortality. Treatment and control groups of chinook salmon will be created as described above. When there is a clear difference in BKD infection between treatment and control fish, we will shift them to water with 120% TDG. All mortalities will be examined for signs of GBD and assayed for BKD. When about 50% of the fish in a tank have died, we will sample the remaining fish to determine if severity of BKD in survivors differs from that in the mortalities.

Task B. Vibriosis

In the laboratory, the mean-time-to-death from *V. anguillarum* is from 3 to 7 days after exposure to the pathogen (Maule et al. 1987, 1989). Because death from *V. anguillarum* happens so rapidly, resistance to this disease depends on the integrity of the fish's epithelium (i.e., skin, gills and gut) -- those surfaces most obviously affected by GBD.

Chronic DGS -- We will expose juvenile chinook salmon to water with 110% TDG for about 20 d at which time we will examine a random sample to document signs of GBD. We will then expose GBD fish and control fish to *V. anguillarum* via the

waterborne method used by Maule et al. (1987, 1989). Because fish do not encounter this pathogen until they enter the estuary, we will shift them to saturated (100% TDG) water at the time of pathogen challenge. We will expose treated and control fish to the pathogen after recovery from signs of GBD. We will collect data on cumulative mortality and mean-time-to-death for DGS-treated fish and controls.

Acute DGS -- To avoid selecting the healthiest individuals in a population prior to the pathogen challenge, our acute DGS exposure will be of a short duration. We found that at 120% TDG at 12° C first mortalities occur after 12 to 36 h. In this experiment we will shift healthy, acclimated fish to water with 120% TDG and monitor the fish hourly. As soon as some fish appear moribund, or after 24 h, we will shift them back to saturated water and expose them to the pathogen. Necropsy and data collection will be as described above.

Data Analyses

Data collected from the disease challenges will include cumulative mortality, mean time-to-death of the fish that die, and severity of infection (BKD only). All data will be checked for normality and significant differences ($p < 0.05$) between treatment and control groups will be determined by parametric (t-test) or non-parametric (Kruskal-Wallis) tests as appropriate. Percent data will be arcsin transformed and tested using a Chi-square test.

f. Facilities and equipment.

The Columbia River Research Laboratory has facilities and equipment adequate for completion of this project. Most special equipment required for this project is owned by the USGS, or was purchased by BPA during previous contract years. The Laboratory has wetlab, drylab, office, boat, vehicle, and computer facilities available for this project. Completion of Objective 2, Task D will require a pressurized swim chamber or deep tank. The BPA has already purchased an apparatus we believe suitable for this task. It was purchased for gas research by the Battelle Pacific Northwest Laboratory. We believe the research has been completed and that the apparatus is presently unused. A similar device could be built using the existing one as a template if this is not the case.

g. References.

- Beeman, J. W., P. V. Haner, and A. G. Maule. *In press*. Evaluation of a new miniature pressure-sensitive radio transmitter. *North American Journal of Fisheries Management*.
- Dawley, E. M., and W. J. Ebel. 1975. Effects of various concentrations of dissolved atmospheric gas on juvenile chinook salmon and steelhead trout. *United States Marine Fisheries Service Fishery Bulletin* 73:787-796.
- Gorham, F. P. 1901. The gas bubble disease of fish and its causes. *Bulletin of the United States Fish Commission* (1899) 19:33-37.
- Gray, R. H., and J. M. Haynes. 1977. Depth distribution of adult chinook salmon

- (*Oncorhynchus tshawytscha*) in relation to season and gas-supersaturated water. Transactions of the American Fisheries Society 106:617-620.
- Knittle, M. D., G. A. Chapman, and R. R. Garton. 1980. Effects of hydrostatic pressure on steelhead survival in air-supersaturated water. Transactions of the American Fisheries Society 109:755-759.
- Maule, A. G., C. B. Schreck, and S. L. Kaattari. 1987. Changes in the immune system of coho salmon (*Oncorhynchus kisutch*) during the parr-to-smolt transformation and after implantation with cortisol. Canadian Journal of Fisheries and Aquatic Sciences 44:161-166.
- Maule, A. G., R. A. Tripp, S. L. Kaattari, and C. B. Schreck. 1989. Stress alters immune function and disease resistance in chinook salmon (*Oncorhynchus tshawytscha*). Journal of Endocrinology 120:135-142.
- Mesa, M. G. 1993. The role of bacterial kidney disease in the vulnerability of juvenile chinook salmon to predation. Report #3 in Poe, T. P., and D. M. Gadowski, editors. Significance of selective predation and development of prey protection measures for juvenile salmonids in the Columbia and Snake River reservoirs. Annual report to Bonneville Power Administration by the U.S. Fish and Wildlife Service, Portland, OR.
- Mesa, M. M., and J. J. Warren. 1997. Predator avoidance ability of juvenile chinook salmon (*Oncorhynchus tshawytscha*) subjected to sublethal exposures of gas-supersaturated water. Canadian Journal of Fisheries and Aquatic Sciences 54:757-764.
- Monan, G. E., R. J. McConnell, J. R. Pugh, and J. M. Smith. 1969. Distribution of debris and downstream-migrating salmon in the Snake River above Brownlee Reservoir. Transactions of the American Fisheries Society 98:239-244.
- Smith, J. R. 1974. Distribution of seaward-migrating chinook salmon and steelhead trout in the Snake River above Lower Monumental Dam. Marine Fisheries Review 36:42-45.
- Thorne, R. E., C. J. McClaine, J. Hedgepeth, E. S. Kuehl, and J. Thorne. 1992. Hydroacoustic surveys of the distribution and abundance of the fish in Lower Granite Reservoir, 1989-1990, Final Report. Prepared by Biosonics, Seattle, WA for U. S. Army Corps of Engineers, Walla Walla, WA, contract DACW68-C-0022.
- Weitkamp, D. E. 1976. Dissolved gas supersaturation: live cage bioassays at Rock Island Dam, Washington. Pages 24-36 in Fickeisen and Schneider, editors. Gas Bubble Disease. 1976. CONF-741033, Technical Information Center, Energy Research and Development Administration, Oak Ridge, Tennessee.
- Weitkamp, D. E. and M. Katz. 1980. A review of dissolved gas supersaturation literature. Transactions of the American Fisheries Society 109:659-702.

Section 8. Relationships to other projects

This is not intended to duplicate the Relationships table in Section 3. Instead, it allows for more detailed descriptions of relationships, includes non-interdependent relationships, and includes those not limited to specific Bonneville projects.

This project is part of a combined effort to understand the relations between supersaturated water and GBD. In 1996 there were five research projects conducted in McNary reservoir of the Columbia River to address this topic. They were designed to determine if the results of the Biological Monitoring Program samples in a juvenile fish collection facility reflected results from fish in the forebay (BPA # 9300802; performed by Columbia Inter-Tribal Fish Commission), if results of the Biological Monitoring Program were probable given individual exposure histories (this study and one COE study based on fixed hydroacoustic surveys), and to generate data for a mortality model being developed by the COE (this study and two studies funded by COE; performed by US Geological Survey and COE). The University of Washington Center for Quantitative Sciences is also interested in the data from this study to update the subroutine describing mortality due to GBD in their CRiSP model of fish survival.

Section 9. Key personnel

Key personnel in this project include Dr. Alec Maule (project leader, 0.75 FTE), John Beeman (principal investigator of field studies, 1.0 FTE), and Matt Mesa (principal investigator of laboratory studies, 0.5 FTE). Dr. Maule oversees research under each project objective, while Mr. Beeman and Mr. Mesa participate in and direct field and laboratory research. Brief resumes are attached.

Resume of Alec G. Maule

Education

B.A., University of California, Riverside (Psychology) 1969
B.S., California Polytechnic University, San Luis Obispo (Natural Resource Management) 1979
M.S., Oregon State University (Fisheries Science) 1982
Ph.D., Oregon State University (Fisheries Science) 1989

Employment

Assistant Professor of Fisheries (Courtesy), OSU (1991-present)
Adjunct Associate Professor of Biology, Portland State University (1992-present)

Research Physiologist, USGS, BRD, Columbia River Res. Lab. (1991-present)

Publications (most recent 5 of 29)

Maule, A.G., and M.G. Mesa. 1994. Efficacy of electrofishing to assess plasma cortisol concentration in juvenile chinook salmon passing hydroelectric dams on the Columbia River. *North American Journal of Fisheries Management* 14:334-339.

Maule, A.G., D. Rondorf, J. Beeman, and P. Haner. 1996. Incidence and severity of *Renibacterium salmoninarum* in spring chinook salmon in the Snake and Columbia rivers. *Journal of Aquatic Animal Health* 8:37-46. (Finalist for Best Paper in the journal for 1996).

Haner, P. V., J. C. Faler, R. M. Schrock, D. W. Rondorf, and A. G. Maule. 1995. Skin reflectance as a non-lethal measure of smoltification for juvenile salmonids. *North American Journal of Fish Management* 15:814-822.

Maule, A.G., R. M. Schrock, C. Slater, M. S. Fitzpatrick, and C. B. Schreck. 1996. Immune and endocrine responses of adult spring chinook salmon during freshwater migration and sexual maturation. *Fish and Shellfish Immunology* 6:221-233.

Beeman, J. W., P. V. Haner, and A. G. Maule. *In press*. A new miniature pressure-sensitive radio transmitter. *North American Journal of Fisheries Management*.

Professional Service

I am currently an Associate Editor for the *Journal of Aquatic Animal Health*
American Fisheries Society

Fish Health Section

| | |
|---|---------|
| Snieszko Graduate Award Committee (Chair) | 1989-91 |
|---|---------|

Physiology Section (Charter member)

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| Vice Pres., Pres.-elect, Pres., Past-Pres. | 1993-97 |
|--|---------|

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| Awards Committee (Chair) | 1997-98 |
|--------------------------|---------|

Oregon Chapter

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| AFS Legislative Committee | 1983-84 |
|---------------------------|---------|

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| AFS Oregon Annual Meeting, Program Committee | 1985-93 |
|--|---------|

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|---------------------------------|---------|
| Director of Internal Committees | 1989-90 |
|---------------------------------|---------|

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|------------------------------|---------|
| Pres.-elect/Pres./Past Pres. | 1990-93 |
|------------------------------|---------|

Regional Committees

| | |
|---------------------|-----------------|
| Dissolved Gas Team. | 1995 - present. |
|---------------------|-----------------|

| | |
|--|-----------------|
| Grand Coulee Dam Dissolved Gas Committee (Chair) | 1996 - present. |
|--|-----------------|

Resume of John W. Beeman

Present Position: Research Fishery Biologist

U. S. Geological Survey

Northwest Biological Science Center, Columbia River Research Laboratory

Cook-Underwood Road

Cook, Washington 98605

Current assignment: Team leader of research project addressing the effects of dissolved gas supersaturation on juvenile salmonids.

| <u>Education:</u> | <u>Degree/Course</u> | <u>Date</u> | <u>School</u> |
|-------------------|----------------------|-------------|----------------------------|
| | Bachelor of Science | 1981 | Saint John's University |
| | Master of Arts | 1984 | University of South Dakota |

Experience:

| | |
|---------------|---|
| 1985-present: | Research Fishery Biologist, Columbia River Research Laboratory, Cook, WA. |
| 1984 | Laboratory Technician, heavy metals analysis, University of South Dakota/U.S. Army Corps of Engineers |
| 1983 | Laboratory Technician, zooplankton analysis, University of South Dakota/South Dakota Department of Game, Fish and Parks |

Expertise:

Pen-rearing of juvenile salmonids

Juvenile salmonid seaward-migration and smoltification

Non-lethal measures of smoltification assessment; radio-telemetry of juvenile salmonids

Five most recent publications:

- Schrock, R. M., J. W. Beeman, D. W. Rondorf, and P. V. Haner. 1994. A microassay for gill sodium, potassium-activated ATPase in juvenile pacific salmonids. Transactions of the American Fisheries Society 123:223-229.
- Beeman, J. W. and J. F. Novotny. 1995. Adult production of fall chinook salmon reared in net-pens in backwaters of the Columbia River. American Fisheries Society Symposium 15:261-266.
- Beeman, J. W., D. W. Rondorf, M. E. Tilson, and D. A. Venditti. 1995. A nonlethal measure of smolt status of juvenile steelhead based on body morphology. Transactions of the American Fisheries Society 124:764-769.
- Maule, A. G., D. W. Rondorf, J. Beeman, and P. Haner. 1996. Incidence of *Renibacterium salmoninarum* infections in juvenile hatchery spring chinook salmon in the Columbia and Snake rivers. Journal of Aquatic Animal Health 8:37-46.
- Beeman, J. W., P. V. Haner, and A. G. Maule. *In press*. Evaluation of a new miniature pressure-sensitive radio transmitter. North American Journal of Fisheries Management.

Resume of Matthew G. Mesa

Experience

| | |
|--------------|---|
| 1991-Present | Research Fishery Biologist, U.S. Geological Survey, Biological Resources Division, Columbia River Research Lab, Cook, WA |
| | <u>Current responsibilities:</u> Team leader on research projects addressing the effects of dissolved gas supersaturation on juvenile salmonids and evaluating predator-prey relations in Columbia River fishes |
| 1989-1991 | Fishery Biologist, U.S. Fish and Wildlife Service, Seattle-NFRC, Columbia River Field Station, Cook, WA |
| 1986-1989 | Fishery Biologist/CEA Appointee, Seattle-NFRC, Oregon Cooperative Fisheries Research Unit, Oregon State University, Corvallis, OR |

1984-1986 Fishery Biologist, U.S. Fish and Wildlife Service, Seattle-NFRC,
Columbia River Field Station, Cook, WA

| <u>Education:</u> | <u>School</u> | <u>Degree and Date Received</u> |
|-------------------|---|--|
| | California Polytechnic State University at San Luis Obispo | B.S., Res. Mgt. 1984 |
| | Oregon State University | M.S., Fisheries, 1989 |
| | Oregon State University | Advancement to candidacy for Ph.D, 1995 |

Expertise: My areas of expertise include predator-prey interactions in fishes, fish behavior and performance, and general and stress physiology of fishes

Publications and Reports (five most relevant)

- Mesa, M.G. and C.B. Schreck. 1989. Electrofishing mark-recapture and depletion methodologies evoke behavioral and physiological changes in cutthroat trout. Transactions of the American Fisheries Society 118:644-658.
- Mesa, M.G. 1991. Variation in feeding, aggression, and position choice between hatchery and wild cutthroat trout in an artificial stream. Transactions of the American Fisheries Society 120:723-727.
- Mesa, M.G. 1994. Effects of multiple acute stressors on the predator avoidance ability and physiology of juvenile chinook salmon. Transactions of the American Fisheries Society 123:786-793.
- Mesa, M.G., T.P. Poe, D.M. Gadomski, and J.H. Petersen. 1994. Are all prey created equal? A review and synthesis of differential predation on prey in substandard condition. Journal of Fish Biology 45 (Supplement A):81-96.
- Mesa, M.G., T.P. Poe, A.G. Maule, and C.B. Schreck. *In press*. Vulnerability to predation and physiological stress responses in juvenile chinook salmon experimentally infected with *Renibacterium salmoninarum*. Canadian Journal of Fisheries and Aquatic Sciences.

Section 10. Information/technology transfer

Results will be disseminated in oral and written formats. Written results will include quarterly and annual reports to BPA and publications in peer-reviewed journals. Information will be presented orally at local, regional, and national meetings.